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FLEET TECHNOLOGY LIMITED
A FLEET AEROSPACE COMPANY

TP 8015E

Development of a Research Plan for Full Scale Testing, Data Analysis and Modeling of the Propulsion Train of a Class IV Icebreaker with Nozzled Propellers

Final Report

June, 1989

Prepared for

Transportation Development Centre

Transport Canada

by

D.N. Bruce Cowper

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Language Notice

Un sommaire en français de ce document est inclus avant la table des matières.

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This program has been conducted with the support of the Transportation Development Centre of Transport Canada, an Agency of the Canadian Federal Government located in Montreal, Quebec.

Fleet Technology Limited acted as the principal contractor to the project with overall responsibility for the conduct of the field observations, development of a research plan, presentation of the findings, and the preparation of the final report.

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Mr. Ian Glen	President

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16. Abstract

The main objective of this project was to organize and develop, in a joint effort with the U.S. Coast Guard, a research plan for the full-scale instrumentation and analysis of an Arctic Class IV vessel propulsion system having a ducted propeller arrangement. An opportunity to produce a research plan for the conduct of a further program of dedicated tests presented itself through the planned drydocking of BeauDril's class IV icebreaker the M.V. Ikaluk.

Field observations were conducted from October 16 to October 24, 1988, in the Beaufort Sea, near a drilling site north east of Deadhorse, Alaska, and on a voyage from the drill site to Herschel Island, Yukon. The results from these observations indicated that it is feasible to instrument the M.V. Ikaluk, during its drydocking period, for nozzle loads, stern tube bearing loads, and other propulsion system parameters. A location for the data acquisition system and preliminary instrumentation techniques was developed with BeauDril Engineers.

Throughout the project, discussions regarding the proposed full scale tests were conducted with all the parties involved; these discussions and other internal investigation by Fleet Technology resulted in the development of a detailed research plan complete with a cost estimate and work schedule. This report describes in detail the field observations and the research plan for the conduct of these tests, including the cost estimate and a project schedule.

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16. Resumé

La présente recherche a eu pour but principal d'organiser et de mettre au point, conjointement avec l'U.S. Coast Guard, un plan visant à doter un système de propulsion sous tuyère de cote arctique IV d'une chaîne de mesure permettant de recueillir des données en vraie grandeur. La mise en bassin de radoub envisagée pour le brise-glace de cote arctique IV IKALUK appartenant à BeauDril a fourni l'occasion d'élaborer un plan de recherche visant de nouveaux essais spécialisés.

Une campagne d'observations in situ a été menée du 16 au 24 octobre 1988, d'abord dans la mer de Beaufort au large d'un forage au nord-est de Deadhorse (Alaska), puis au cours d'un périple dont la destination était un autre site sur Herschel Island (Yukon). Les résultats ont montré qu'il est possible de doter l'Ikaluk, au moment de sa mise en bassin de radoub, d'une chaîne de mesure permettant le mesurage de paramètres de propulsion comme la charge des glaces sur la tuyère, sur le palier de tube d'étambot et d'autres organes du système propulsif. L'emplacement réservé à la chaîne de mesure a été déterminé avec l'aide des ingénieurs de BeauDril.

Tout au long, les essais envisagés ont été débattus par les parties intervenantes. Ces discussions et autres investigations menées par Fleet Technology, ont débouché sur un plan de recherche détaillé, comportant un devis estimatif ainsi qu'un calendrier des travaux. Le présent rapport rend compte de la campagne d'observations in situ et décrit le plan de recherche élaboré, le devis estimatif et le calendrier des travaux.

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SUMMARY

During the past fifteen years, Canada has achieved a position of world leadership in many aspects of the technology of arctic marine transportation. A prominent feature of the Canadian work has been the emphasis upon full-scale engineering data and operational experience to guide and inform the technology development process. The two most extensive programs of propulsion machinery measurements have been the 1984 M.V. Robert Lemeur Propeller Blade Load Measurement Programme and the 1986 M.V. Kalvik Propulsion System Full Scale Test Programme. Both were cooperative programmes involving the Transportation Development Centre and private industry interests and represent unique sources of full-scale data on a world-wide basis. The results from the M.V. Kalvik, as well as that from other vessels, helped develop a system of computer models for analyzing the dynamic response of a generalized ice class shaftline.

An opportunity to produce a research plan for the conduct of a further program of dedicated tests presented itself through the planned drydocking of BeauDril's class IV icebreaker, the M.V. Ikaluk. BeauDril have replaced the bearings in their Class IV Icebreaker the M.V. Miscaroo and have plans to replace the bearings on its sister ship the M.V. Ikaluk. The fact that these bearings were severely damaged confirms the importance of developing sound engineering design principles for ice class shafting systems in order to reduce the incidence of such failures.

The main objective of this project was to organize and develop, in a joint effort with the U.S. Coast Guard, a research plan for the full-scale instrumentation and analysis of an Arctic Class IV vessel propulsion system having a ducted propeller arrangement.

Field observations were conducted from October 16 to October 24, 1988 in the Beaufort Sea, near a drilling site north east of Deadhorse, Alaska, and on a voyage from the drill site to Herschel Island, Yukon. These observation were conducted onboard the M.V Miscaroo (sister ship of the M.V. Ikaluk), the M.V. Kalvik, and the M.V. Terry Fox, with two engineers from NKF Engineering, Columbia, Maryland, U.S.A. and two engineers from the U.S. Coast Guard's Naval Engineering branch. The results from these observations indicated that it is feasible to instrument the M.V. Ikaluk, during its drydocking period, for nozzle loads, stern tube bearing loads, and other propulsion system parameters. A location for the data acquisition system and preliminary instrumentation techniques was developed with BeauDril engineers. There was also a unique opportunity during the field observations to be involved in the escort mission of a barge by two Class II and two Class IV vessels in pressurized multi-year ice.

Throughout the project, discussions regarding the proposed full-scale tests were conducted with all the parties involved: BeauDril Limited, U.S. Coast Guard, Transportation Development Centre, Canadian Coast Guard, Lloyd's Register, Bearing Machinist, and NKF Engineering. These discussions and other internal investigation by Fleet Technology resulted in the submission of a detailed research plan complete with a cost estimate and work schedule. This report describes in detail the field observations and the research plan for the conduct of these tests, including the cost estimate and a project schedule.

The drydock work on the M.V. Ikaluk is scheduled for April of 1989. The schedule for the conduct of the full-scale trials is governed by this date; therefore, it is recommended that the approval to proceed with the research plan be given by March 1, 1989 to permit ordering of long lead-time items and testing on the proposed instrumentation equipment.

SOMMAIRE

Au cours des quinze dernières années, le Canada est devenu le chef de file dans la recherche sur les technologies appliquées au transport maritime dans l'Arctique. Il s'est particulièrement distingué dans l'acquisition des données en vraie grandeur exploitables par les ingénieurs, et dans la maîtrise des techniques de mesure correspondantes visant à orienter et à alimenter le processus de développement technologique. Deux grands programmes de mesurage des contraintes sur les systèmes propulsifs sont à la base de cette maîtrise: mesurage de la charge des glaces sur les pales d'hélice, entrepris en 1984 à bord du Robert-Lemeur, et essais de propulsion en vraie grandeur à bord du brise-glace Kalvik en 1986. La recherche à caractère coopératif menée conjointement par le Centre de développement des transports et le secteur privé, a débouché sur des résultats particulièrement fructueux. Les résultats des essais à bord du Kalvik et autres navires, ont permis l'élaboration d'une série de modèles informatiques pour l'analyse de la réponse dynamique de la ligne d'arbre d'un navire de cote arctique.

La mise en bassin de radoub prévue du brise-glace Ikaluk de cote arctique IV, appartenant à BeauDril, a fourni l'occasion d'élaborer un plan visant la conduite d'un nouveau programme d'essais spécialisés, à la lumière des constatations faites lors de la mise en radoub du brise-glace de cote arctique IV Miscaroo. Ce navire, jumeau de l'Ikaluk, avait eu le palier de tube d'étambot sérieusement endommagé par les glaces, lequel a dû être remplacé. BeauDril a dû changer ce palier et envisager la même intervention sur l'Ikaluk. Les importants dommages constatés montrent la nécessité de formuler, à l'égard du système propulsif, des principes de calcul bien fondés grâce auxquels la fréquence de ce type d'avarie pourra être réduite.

La présente recherche a eu pour but principal d'organiser et de mettre au point, conjointement avec l'U.S. Coast Guard, un plan visant à doter un système de propulsion sous tuyère de cote arctique IV d'une chaîne de mesure permettant de recueillir des données en vraie grandeur.

Une campagne d'observations in situ a été menée du 16 au 24 octobre 1988, d'abord dans la mer de Beaufort au large d'un forage au nord-est de Deadhorse (Alaska), puis au cours d'un périple dont la destination était un autre site sur Herschel Island (Yukon). Les observations ont été faites à bord du Miscaroo et de l'Ikaluk, deux navires jumeaux, et du Terry-Fox, avec la collaboration de deux ingénieurs prêtés par la NKF Engineering de Columbia (Maryland) et de deux autres par l'U.S. Coast Guard, service d'architecture navale. Les résultats ont montré qu'il est possible, au moment de sa mise en radoub, de doter l'Ikaluk d'une chaîne de mesure permettant le mesurage de paramètres de propulsion tels que la charge des glaces sur la tuyère, le palier de tube d'étambot et d'autres organes du système propulsif. L'emplacement réservé à la chaîne de mesure a été déterminé avec l'aide des ingénieurs de BeauDril. En outre, l'occasion s'est présentée durant la campagne d'observations de participer à une mission d'escorte d'une barge, utilisant pour cela deux navires de cote arctique II, relayés par deux autres de cote IV, en raison de la présence de glaces de pression de plusieurs années.

Tout au long, les essais envisagés ont été débattus par les parties intervenantes: BeauDril Limited, l'U.S. Coast Guard, le CDT ainsi que la Garde côtière canadienne, Lloyd's Register, Bearing Machinist et NKF Engineering. Ces discussions, et autres investigations menées par Fleet Technology, ont débouché sur un plan de recherche détaillé, comportant un devis estimatif ainsi qu'un calendrier des travaux. Le présent rapport rend compte de la campagne d'observations in situ et décrit le plan de recherche élaboré, le devis estimatif et le calendrier des travaux.

La mise en bassin de radoub de l'Ikaluk est prévue pour avril 1989. Comme la date des essais en vraie grandeur est conditionnée par cette dernière, il est recommandé que l'approbation du plan de recherche soit arrivée le 1er mars 1989, de manière à pouvoir commander les articles dont la livraison risque de prendre un certain temps et vérifier la chaîne de mesure avant le départ.

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1. INTRODUCTION

During the past fifteen years the Canadian and the United States governments have sponsored unique research in many aspects of the technology of arctic marine transportation. A prominent feature of this work has been the emphasis upon the full scale engineering data and operational experience to guide the development of technology. The two most extensive programs of propulsion machinery measurements have been the 1984 M.V. Robert Lemeur Propeller Blade Load Measurement Programme and the 1986 M.V. Kalvik Propulsion System Full Scale Test Programme, each of which were cooperative programmes involving Canada's Transportation Development Centre and private industry interests. Both programmes represent unique sources of full scale data on a world wide basis. The tests done on the M.V. Robert Lemeur provided the loads and stresses on the propeller blade of a nozzled icebreaker. The tests done on the M.V. Kalvik provided data, for the first time, on the loads generated throughout a salt water lubricated rubber stave type stern tube bearing, due to propeller ice forces. This data coupled with other propulsion system measurements provided excellent quantitative data and a good qualitative picture of the response of this unducted propeller to ice-propeller interaction. However, full scale data for the bearing loads for an icebreaker fitted with a propeller duct does not exist . The results of the M.V. Kalvik as well as that from other vessels helped develop a system of computer models for analyzing the dynamic response of a generalized ice class shaftline.

Propeller ducts (Kort nozzles) have been used on icebreaking ships since the 1970s. A number of Canadian vessels have been outfitted with these. The first class two icebreaking vessel with a nozzle was the M.V. Arctic, launched in 1977. The largest nozzle fitted for icebreaking service is the 5.35 m diameter duct on the icebreaking supply vessel Canmar Kigoriak. To date only one analytical study has been done on the strength requirements of nozzles for ice transiting ships (Transport Canada Report TP # 6837E). One of the conclusions of the work was that a need exists for full scale verification of the nozzle/ice impact scenarios that had been proposed. At full scale there exists a limited amount of data from tests done in Finland on relatively low horsepower installations, in particular tests on the 1.95 metre diameter 1100 HP nozzle propeller on the fishing vessel Jarvsaar, and in Canada on the Canmar ice breakers Kigoriak and Robert Lemeur. The tests on the Jarvsaar involved measurements of ice impact loads on the nozzle. The tests on the Canmar vessels primarily examined the mechanical loading of the propellers and shafting due to ice entering and blocking the ducts. However, no systematic investigation

of the ice impact loads upon ducts or the loads on the shaft bearings of vessels fitted with ducts have been carried out for arctic icebreakers.

The M.V. Ikaluk is an ASPPR Class IV icebreaking supply vessel fitted with two 3.75 metre diameter nozzles and controllable pitch propellers transmitting 7450 HP each. In the winter of 1988/89 the vessel will be drydocked at Herschel Island in the Yukon for routine maintenance and repairs. The ship is owned by Gulf Canada Resources Limited (GCRL) as part of their fleet of marine equipment deployed to carry out oil exploration in the Beaufort Sea. During April of 1989 both shafts will be removed and a new set of stern tube bearings will be installed.

This drydocking allows for an opportunity to instrument one set of the new stern tube bearings and a nozzle to measure their respective loading during icebreaking operation. Other measurements of basic propulsion systems parameters such as Shaft Torque, Shaft Thrust, RPM and Engine Fuel Rack can also be obtained. Since both the U.S. Coast Guard and Transport Canada are interested in participating in a full scale test programme resources can be combined to reduce individual costs. Therefore, there is a window of opportunity for obtaining very unique data to help develop current and proposed design criteria and regulatory requirements of ice class shafting systems.

2. FIELD OBSERVATIONS

Field observations were conducted from October 16 to October October 24, 1988 in the Beaufort Sea in the area North East of Deadhorse, Alaska to Herschel Island, Yukon. The following personnel were present:

Fleet Technology Limited	Bruce Cowper
Transportation Development Centre	Pierre Semery
United States Coast Guard	Christopher Cleary
	Kevin Danahy
NKF Engineering	Richard Voelker
	James St. John

The objectives of the field observations were the following:

- Feasibility of instrumenting the stern tube bearings for load, the shaft for movement and bending stress, the nozzle for loads, and other relevant propulsion system parameters.
- The status of existing instrumentation
- Determine potential location for data acquisition equipment and instrumentation cables
- Meet with USCG personnel and determine their requirements
- Interview Captains and Chief engineers on their experience with nozzled and open screw icebreakers

These objectives were fully achieved during the field observations. There was also a unique opportunity to observe the towing of a cargo barge east of Herschel Island, Yukon, through multi-year pressure ice and ridges in excess of 9 metres in thickness.

Discussion with USCG personnel revealed that they are interested in all aspects of the design of nozzles for icebreakers including the bearing loads, shaftline response, engine response, and ice loads induced on the nozzle.

Chronological Account of Activities

October 16, 1988

- Traveled to Anchorage, Alaska
- Meeting with USCG, TDC, and NKF personnel

October 17, 1988

- Traveled to Deadhorse and then to the M.V. Kalvik (Open Screw Vessel)
- Location: Latitude 70° North 15 minutes , Longitude 141° West 30 minutes
- Broke thin level first year ice around Kulluk (Round Drill Ship)
- No significant ice breaking was observed, vessel was operated in largely thin first year ice

October 18, 1988

- On board M.V. Kalvik
- Tour of vessel including machinery spaces
- Interviewed Captain and Chief Engineer
- No significant icebreaking was done

October 19, 1988

- On board M.V. Kalvik
- No significant icebreaking was done
- Broke thin level first year ice in escort of Kulluk to drill site

October 20, 1988

- Transferred to M.V. Miscaroo
- Tour of machinery spaces
- Interviewed Captain and Chief Engineer

October 21, 1988

- On board M.V. Miscaroo
- Observations of maneuvering in thin first year ice 30 cm in thickness
- Observations of ramming in multi year ice 2-3 meters in thickness
- No significant blockage of nozzle
- Ice was not pressurized
- Detailed observations in Appendix A
- Interviews with Captain and Chief Engineer
- Transferred to the M.V. Terry Fox
- Begun transit from drill site to east of Herschel Island, Yukon to help in the escort of a cargo barge.
- Multi year ice floes were transited which required repeated ramming operations

October 22 and 23, 1988

- On board M.V. Terry Fox
- Interviewed Captain and Chief Engineer
- Tour of machinery spaces
- Reached cargo barge and attached towing cable to barge
- The following vessels were involved in the towing operation:

1. M.V. Terry Fox	(2 x 11,600 HP Open Screw)
2. M.V. Kalvik	(2 x 11,600 HP Open Screw)
3. Arctic Ivik	(2 x 3,250 HP Ducted Propellers)
4. Arctic Natsukpok	(2 x 3,900 HP Ducted Propellers)

- The barge was stuck in a pressurized multi and second year ice floe for the previous 3-4 days. The M.V. Kalvik was sent to assist in the towing operation; however, even with the Kalvik, the Arctic Ivik, and the Arctic Natsukpok the barge could not be moved significantly and was stuck for two days prior to a request for the assistance of the M.V. Terry Fox.

- The towing operations are shown in Figures 2.1 to 2.4, and were conducted as follows:
  - Arctic Ivik and Arctic Natsukpok positioned themselves behind the barge and the Arctic Natsukpok pushed the aft of the barge
  - M.V. Terry Fox towed the barge
  - M.V. Kalvik broke a channel parallel to the barge. This relieved pressure from the side of the barge momentarily and allowed the M.V. Terry Fox to make limited progress. This operation continued until the barge was towed free of the pressurized multi and second year ice floe.
  - It is interesting to note that the Arctic Ivik could not progress through the track made by the M.V. Kalvik during transit through the pressurized ice floe, and had to position itself behind the barge for transiting. The track of the Kalvik was closed within 45 seconds.
  - The M.V. Kalvik could maintain steady progress with occasional ramming through the above described ice conditions.
  - When transiting through a pressure ridge the following procedure was used:
    - Kalvik initially broke through the ridge
    - Arctic Natsukpok pushed aft end of barge to rotate barge perpendicular to the ridge
    - Terry Fox pulled barge through ridge with the Arctic Natsukpok assisting by pushing the barge

October 24, 1988

- Left M.V. Terry Fox and travelled to Edmonton

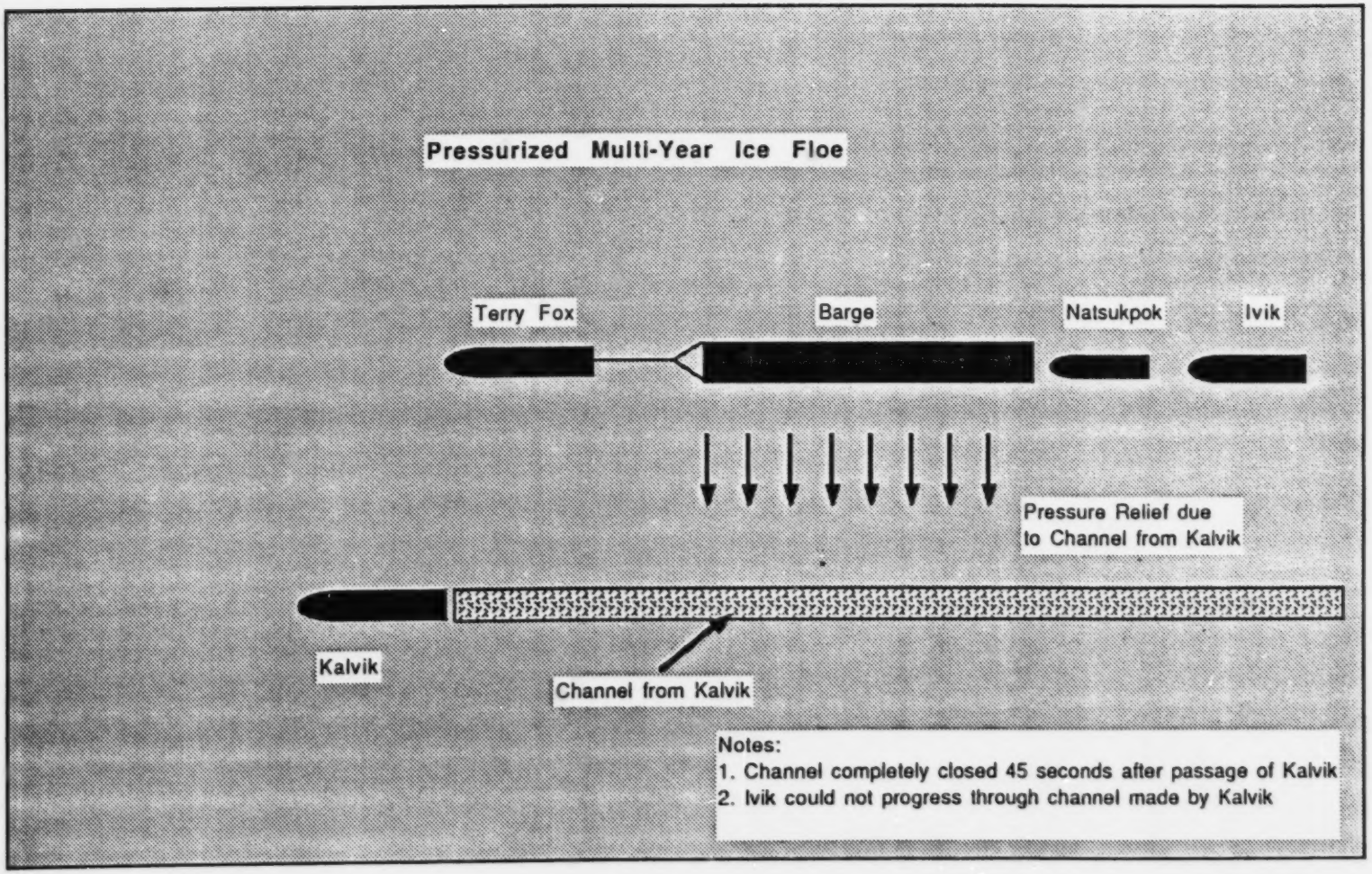


Figure 2.1 Plan View of Barge Escort Operation in a Pressurized Ice Floe

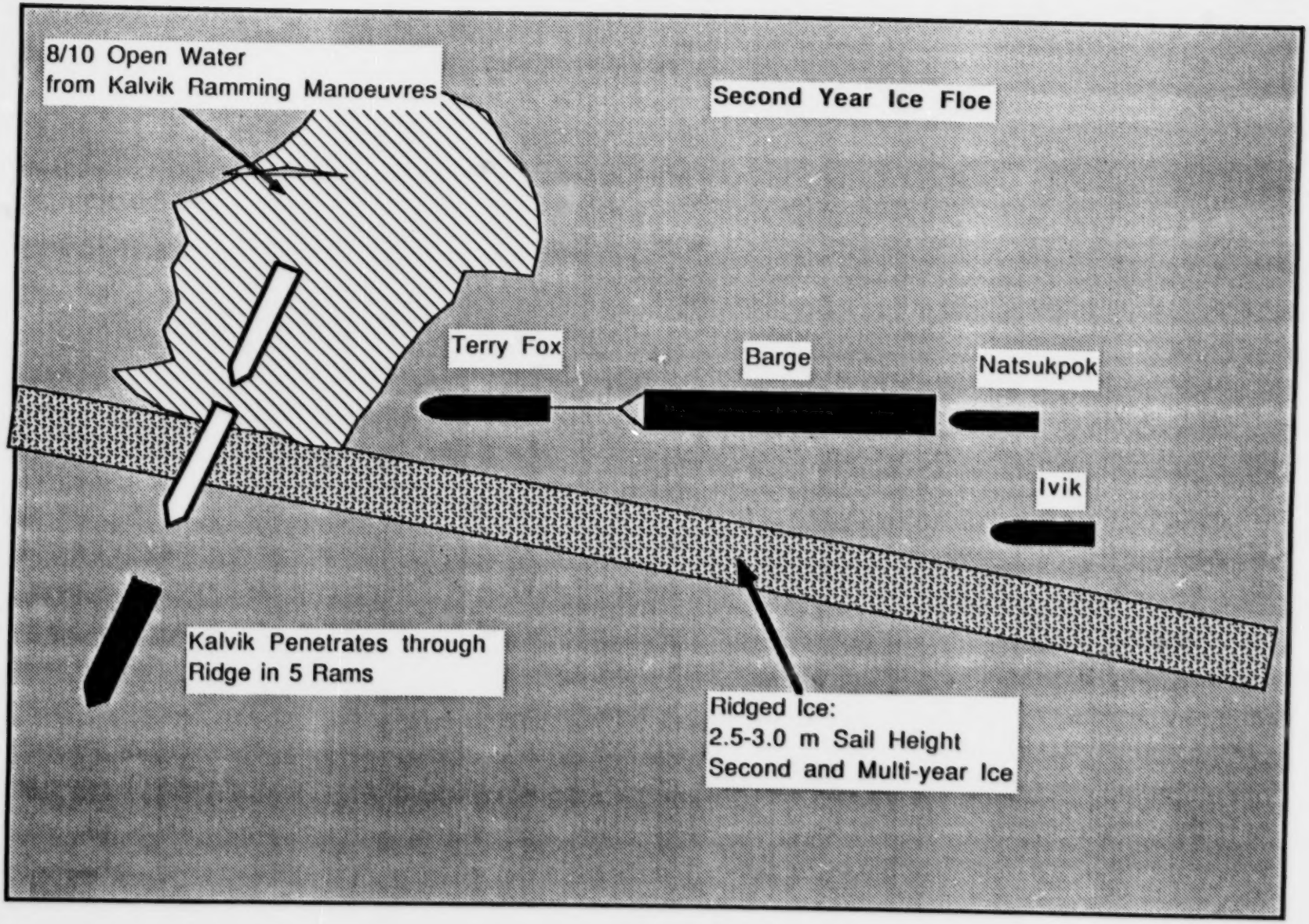


Figure 2.2 Plan View of Barge Escort Operation in a Pressurized Ridge: Stage 1

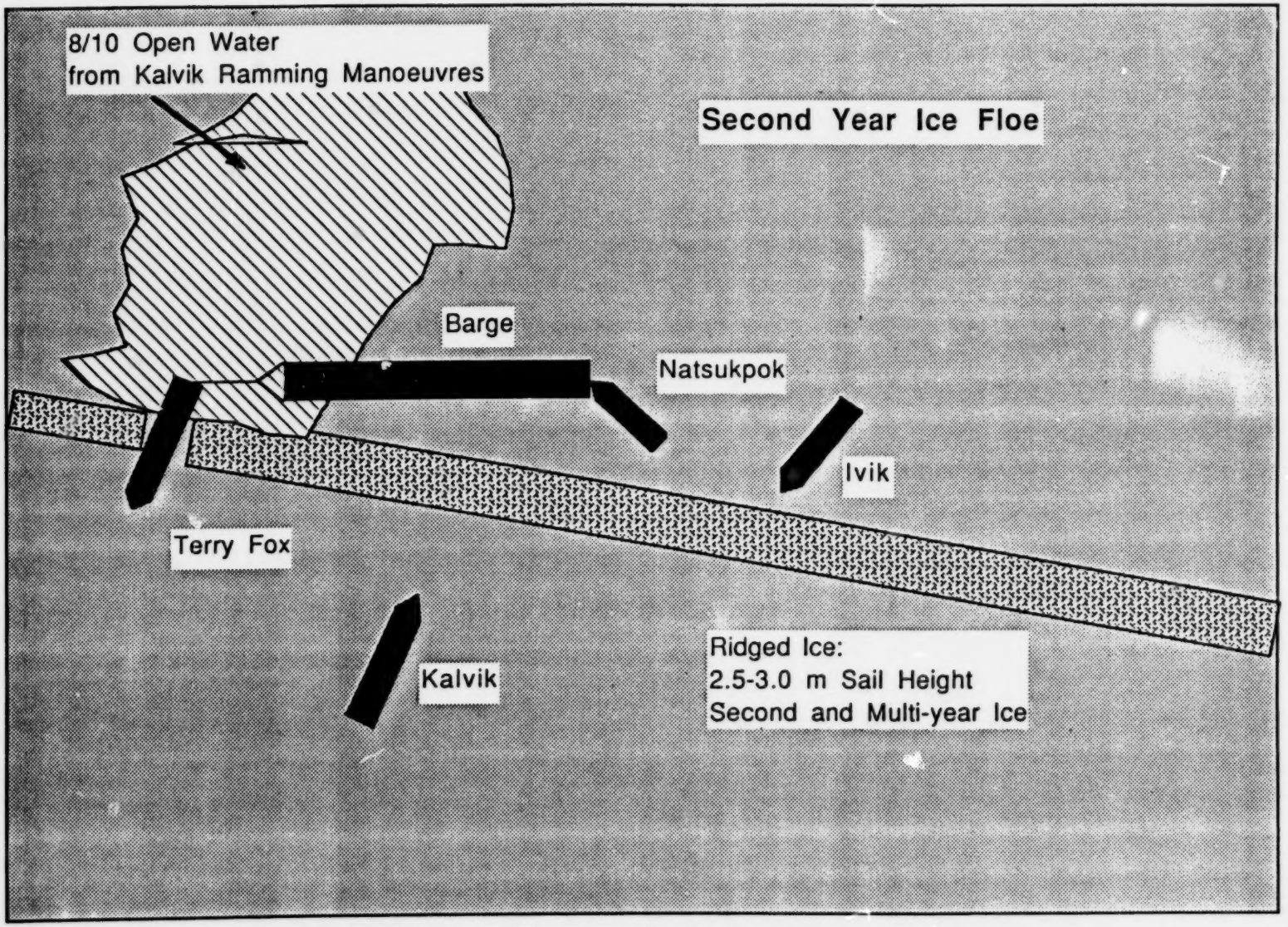


Figure 2.3 Plan View of Barge Escort Operation in a Pressurized Ridge: Stage 2

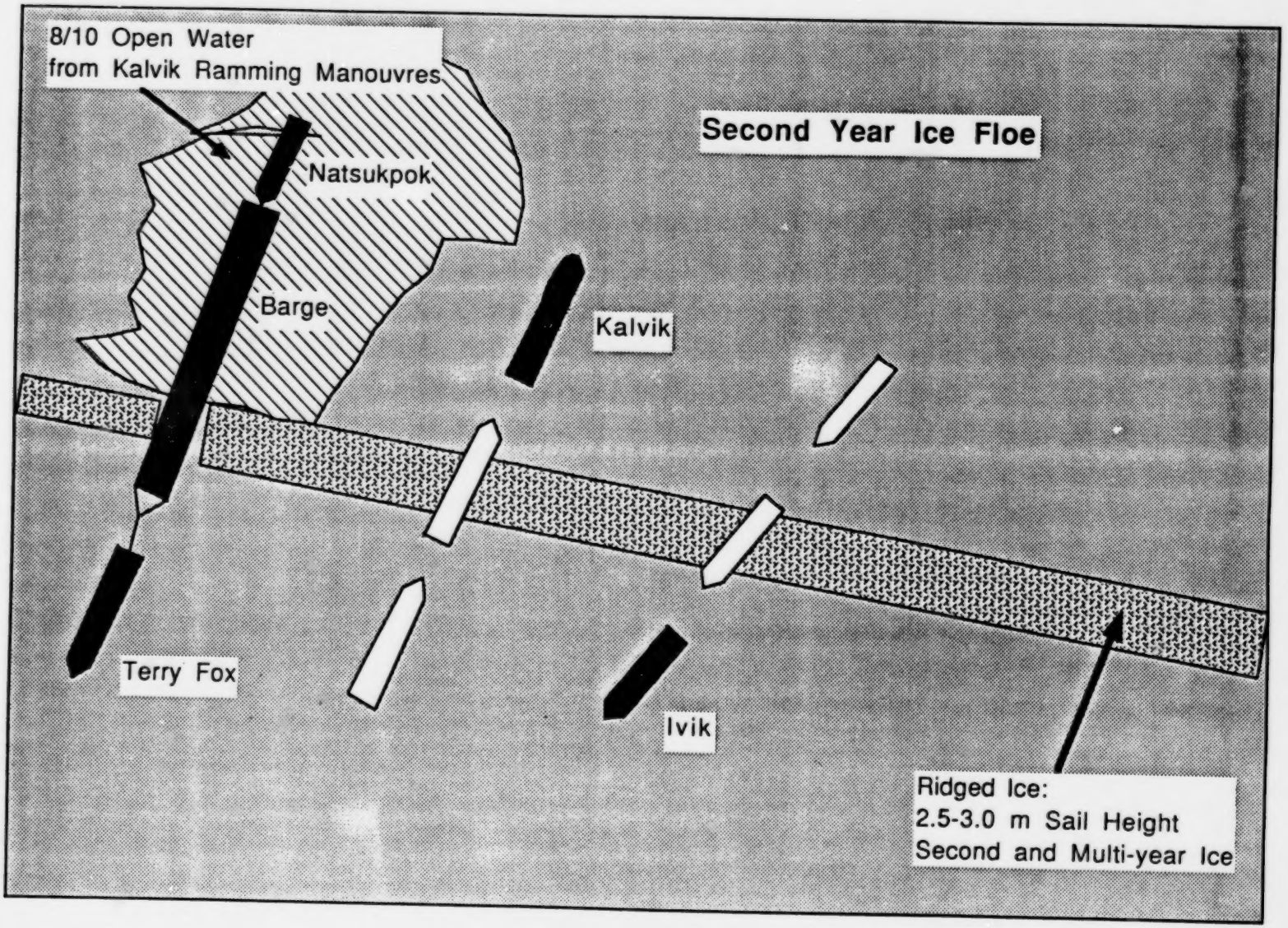


Figure 2.4 Plan View of Barge Escort Operation in a Pressurized Ridge: Stage 3

Results from Interviews with the Captains and Chief Engineers

Captains and engineers were asked for their view on the performance and repairs associated with icebreakers fitted with nozzles versus those without nozzles. The following is a summary of their comments:

- There has been no significant damage to any of the nozzles on icebreakers operating in the Beaufort Sea.
- Damage to the stern tube bearings and the internals of the hub have occurred on vessels fitted with nozzles.
- Blades have been bent on vessels with open screw propellers, however this has not reduced the performance of the vessels and blades are changed during regular drydocking times.
- Icebreakers with a draft of less that 7.0 metres should not be fitted with nozzles because of the severe amount of nozzle blockage that can occur.
- Icebreakers with a draft greater than 7.0 metres with ducted propellers work very well in level ice conditions.
- Icebreakers fitted with ducted propellers do not perform as well as vessels with open screws in pressurized ice conditions, such as pressurized rubble fields and ridges. Experience showed that when transiting through these type of ice conditions the nozzle would become blocked and a reduction in thrust would occur such that progress would be impeded.

Discussion with the chief engineers and the captains resulted in the following conclusions regarding instrumentation:

- It is feasible to instrument Ikaluk for the following:
  - the stern tube bearings for load. New bearings are being installed in April, 1989 and sensors can be installed in Calgary prior to bearings being shipped to the Arctic.
  - the shaft movement forward of the forward stern tube seal
  - the shaft thrust and bending stress
  - the nozzle for ice loads; however, the cost for an extensive instrumentation of the nozzle will be high and the schedule will be tight.

- Existing instrumentation on the Ikaluk includes:
  - Propeller pitch
  - Shaft RPM
  - Shaft Torque (Port Side Only)
  - Rudder Angle

- Location of instrumentation equipment should be in the storage room located aft of the engine room.

3.0 RESEARCH PLAN

3.1. OBJECTIVES

The project has the following main objectives:

1. To measure and report on the full scale ice loads and the dynamic response characteristics of one nozzle on the M.V. Ikaluk.
2. To measure and report on the loads on the stern tube bearings during icebreaking operations of the M.V. Ikaluk..
3. To measure the shaftline response of the M.V. Ikaluk (Shaft torque, thrust, rpm, fuel rack, etc.).
4. To compare the ice loads measured on the nozzle with the proposed regulations for minimum design loads.
5. To compare the loads on the stern tube bearing of open and ducted propellers during ice propeller/nozzle interaction (M.V. Ikaluk vs M.V. Kalvik).
6. To measure shaft torque excursions on the propulsion system for ducted propeller ice milling, clogging, and blockage.
7. To compare shaft torque excursions for ducted versus open propeller systems (M.V. Ikaluk vs M.V. Kalvik).

3.2 Work Statement

Task 1 Liaison and Program Management

This task will be ongoing throughout the duration of the project. This work will involve the following:

- management of project personnel
- coordination and scheduling of subcontractor's work with BeauDril Limited operations
- coordination and scheduling of participants and observers visits onboard
- coordination and scheduling of ship time
- tracking of project costs and progress
- submission of progress reports to the participants

Output

The output of this task will consist of periodically updated schedules and progress reports which will form the basis for decision making to ensure that project objectives are met on schedule and within budget.

Task 2 Instrumentation Design

Objective

To design a reliable efficient instrumentation system to measure the dynamic characteristics (natural frequency, and damping) and ice loads on a nozzle and one set of stern tube bearings on the M.V. Ikaluk.

Approach

The following work will be done to design the instrumentation system:

- Detailed examination of structural drawings
- First order calculation to determine expected stress levels
- Laboratory tests of strain gauges under conditions expected in full scale
- Specification of type of strain gauge to be used
- Determination and specification of exact location and number of strain gauges
- Specification of data acquisition equipment

It was found that there has been no damage to any of the nozzles on icebreakers operating in the Beaufort Sea. Therefore, the existing design specifications may be over estimating the loads. The nozzle design must also ensure that the natural frequency of vibration is not near the blade rate. If the natural frequency is near the blade rate the nozzle must be strengthened even more to provide the additional stiffness to raise the natural frequency above the blade rate (this was in fact the case for the proposed design of the Polar 8 Nozzle). Therefore, the measurement of the full scale natural frequency and damping characteristics of the nozzle will provide important design values. Consideration of these findings resulted in the proposed instrumentation design.

Table 1 lists the proposed signals to be recorded. Figure 3.1 illustrates the shaft line of the M.V. Ikaluk and the proposed measurements to be taken. Figures 3.2 and 3.3 and 3.4 illustrate the proposed location of the gauges to be installed in the nozzle and in the aft and forward stern tube bearings respectively. These signals and strain gauge locations are preliminary, the final design specification will be accomplished upon completion of this task.

Output

Specification of the gauge type, number of sensors, location of sensors, installation technique, and data acquisition equipment.

Table 1 Proposed List of Signals to be Recorded

Description	Number
Nozzle Loads	10
Bearing Loads	20
Shaft Torque	1
Shaft Thrust	1
Shaft Movement	2
Intermediate Bearing Load	2
Engine Fuel Rack	1
Shaft RPM	1
Rudder Angle	1
Rudder Stock Torque	1
Ship Speed	1
Propeller Pitch	1
TOTAL	**42**

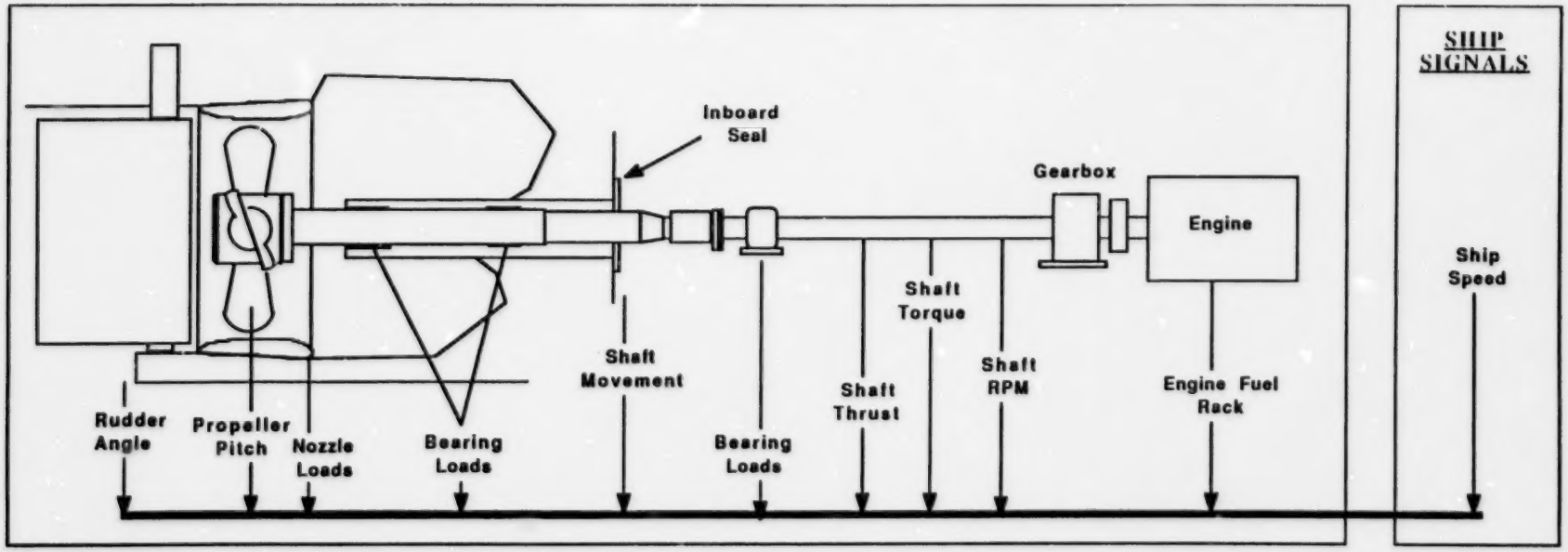


Figure 3.1 Schematic of M.V. Ikaluk Propulsion System Instrumentation

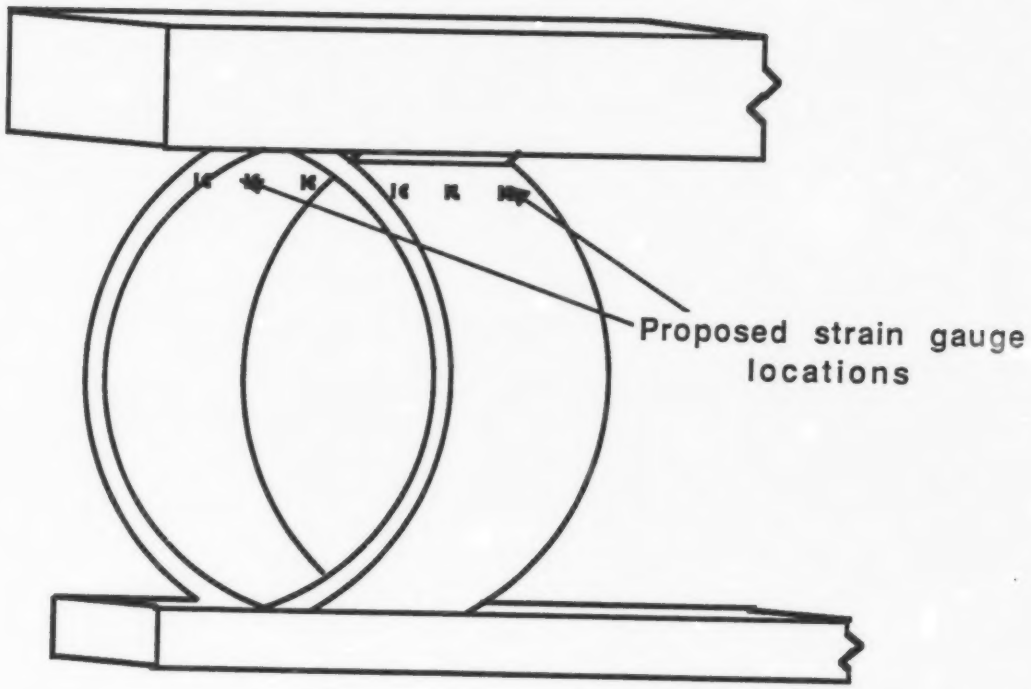
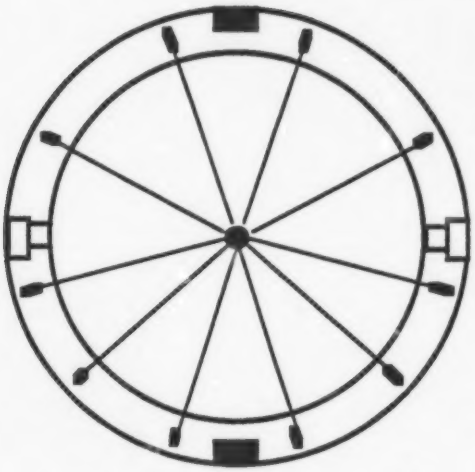
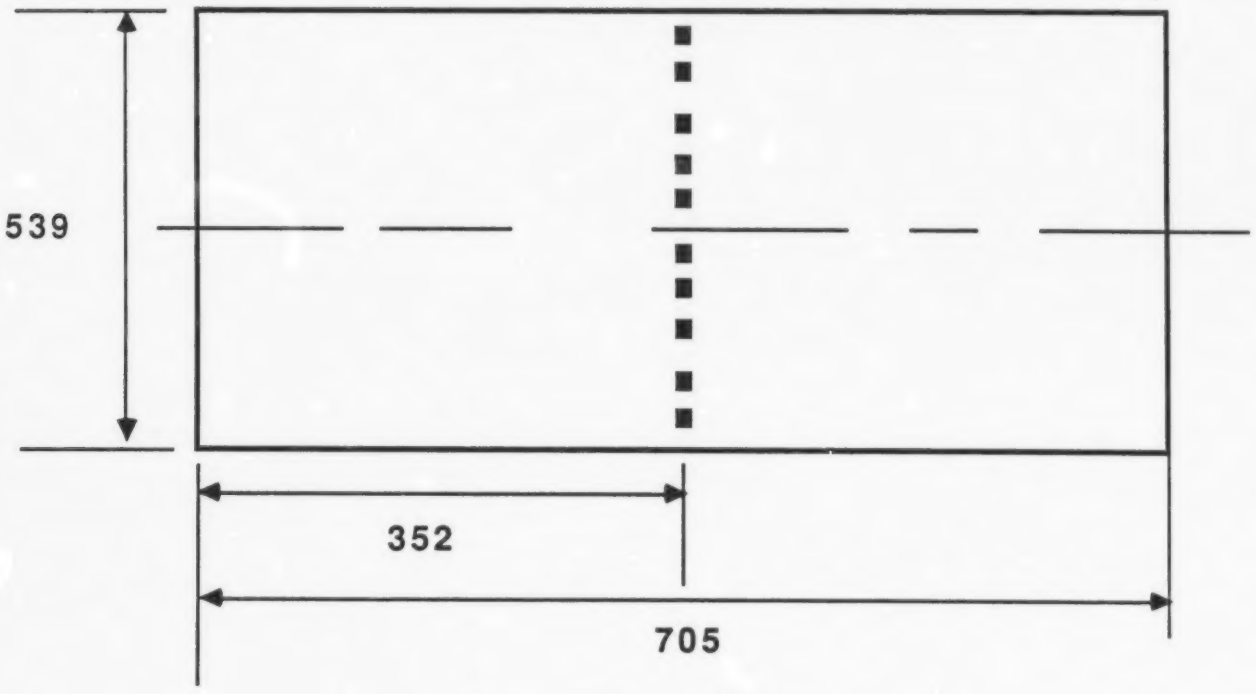


Figure 3.2 Proposed Strain Gauge Locations on Nozzle

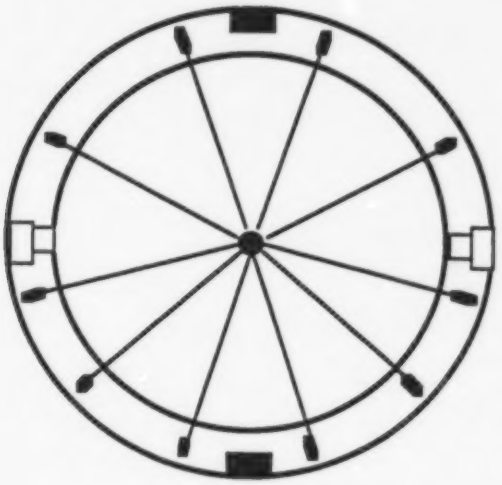


Looking Forward

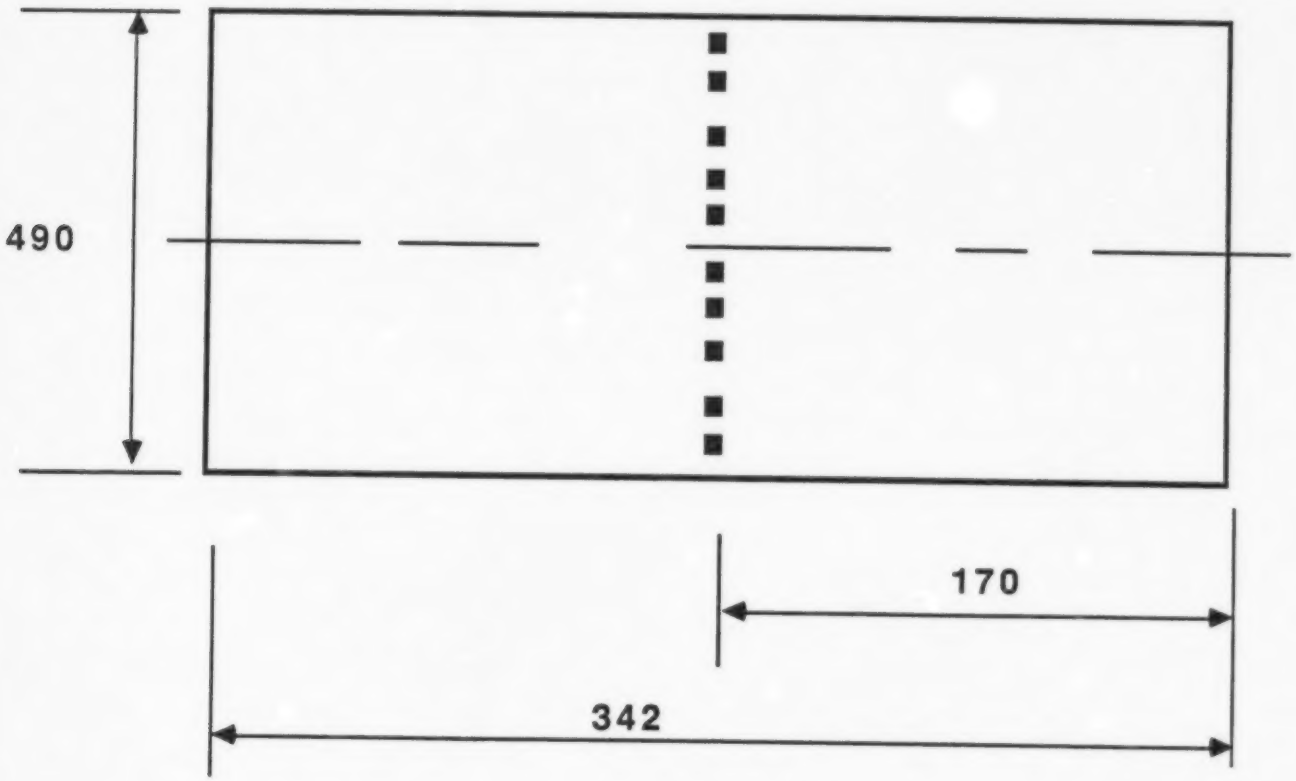


Plan View

Figure 3.3 Proposed Aft Stern Tube Bearing Strain Gauge Locations



Looking Forward



Plan View

Figure 3.4 Proposed Forward Stern Tube Bearing Stain Gauge Locations

Task 3 Instrumentation Procurement and Equipment Rental

Objective

To procure and rent all instrumentation equipment required for the execution of this project.

Approach

The following work will be done for this task:

- Determine suppliers that will deliver instrumentation equipment on time and with a reasonable price
- Obtain ice profiling equipment and package for shipment to the Arctic
- Place orders with suppliers
- Follow up on orders to ensure delivery
- Test equipment after delivered and prior to shipping it to the Arctic
- Package equipment and ship to the M.V. Ikaluk

Output

Instrumentation equipment delivered to the M.V. Ikaluk, and rental costs accounted for.

Task 4 Regulatory Approval

Objective

To obtain approval from the the proper regulatory agency (Lloyd's) for any modifications to existing structure of the M.V. Ikaluk.

Approach

The following work will be done for this task:

- Discussion with regulatory authority on proposed modifications
- Produce engineering drawings for submission to regulatory body
- Modify drawings according to regulatory authority's comments
- Copy drawings for construction personnel to review

Output

Approved drawings of modifications to nozzle and stern tube bearings.

Task 5 Software Development

Objective

To develop a software program for data acquisition and analysis.

Approach

The following work will be done for this task:

- Revise existing data acquisition software for the specific requirements of this project
- Revise existing analysis software to calculate loads from measure data
- Enhance current graphics software for displaying data and results of analysis

Output

Software program for data acquisition and analysis for the proposed full scale test programme on the M.V. Ikaluk

Task 6 Instrumentation Installation

Objective

To install instrumentation in the nozzle, stern tube bearings and shaftline on the M.V. Ikaluk.

Approach

The instrumentation for the nozzle must all be installed on the drydock at Hershel Island, Yukon. The majority of the stern tube bearing instrumentation can be installed in Calgary, Alberta, as the replacement bearings are to be in Calgary until a few days prior to installation in the vessel. The following are the major work tasks that will be done:

- Prepare nozzle for installation of strain gauges
- Install strain gauges in nozzle
- Prepare and machine stern tube for cabling from stern tube bearings
- Machine new stern tube bearings for strain gauge installation
- Mount strain gauges on new bearings
- Install data acquisition unit
- Install shaftline instrumentation
- Run all cabling to data acquisition unit
- Test the data acquisition system and all sensors

Output

Fully instrumented nozzle, stern tube bearing, and shaftline.

Task 7 Calibration

Objective

Obtain calibration factors to convert measured strain to applied load.

Approach

The following work will be done for calibration of the strain gauge sensors:

Nozzle Calibration:

- Prepare area around nozzle to apply loads including welding pad eyes as needed
- Connect load sensors, chains, loading collars, hydraulic rams, and associated equipment
- Apply load to nozzle in the radial and longitudinal direction at various locations
- Measure the corresponding strain gauge responses
- Calculate the calibration factors
- Sensitivity analysis of calibration factors to estimate accuracy of calculated load from strain gauge readings.
- Measure the dynamic response characteristics of the nozzle in drydock (Damping and natural frequency) by applying an impact load an measuring the response.

Bearing Calibration

- Prepare a load platten and hydraulic ram to lay on surface of bearing
- Apply load on area around each gauge location
- Measure the corresponding strain gauge responses
- Calculate the calibration factor for each gauge to convert measured strain to applied local pressure
- Measure the strain gauge response as shaft is re-installed into vessel
- Calculate the static load using the calibration factors and the measured strain. Compare this load with the load calculated from the static alignment measurement.

Output

Calibration factors for converting strain measurements to applied loads.

Task 8 Field Data Collection

Objective

To execute a dedicated set of full scale tests and collect data on an opportunity basis.

Approach

The software will be running continuously to detect and record all sensor responses to ice/propeller/nozzle interaction during the field data collection. A total of five (5) dedicated ship days and approximately ten (10) days on an opportunity basis will be used for the field data collection phase. Since the vessel will be required to break ice as part of its normal operation there should be ample opportunity to collect data during the 10 days after the dedicated tests. The following work will be done for this task:

- Execute the following manoeuvres and record the sensor responses:
  - level icebreaking ahead (1-2 meters in thickness) at various speeds
  - backing in ice
  - ramming multi-year ridges
  - ramming first year ridges
  - turning in level ice
  - Star turn in level ice
- Measure the following ice conditions:
  - thickness
  - salinity and temperature profile for ice strength calculations
  - ridge profile

- Static alignment measurement
- Preliminary data analysis to determine ice loads on the nozzle, bearing, and shaftline
- Detailed log documenting ships operations, sea and ice conditions, environmental conditions, and other relevant information
- Collect data on an opportunity basis and conduct a preliminary analysis.

Output

A trip report with the preliminary data analysis, ice conditions, and a detailed log of the field data collection operation. Data disks containing all the information recorded to be used for further data analysis.

Task 9 Data Analysis

Objective

To determine the ice loads on the nozzle and stem tube bearings based upon the full scale measurements. Results of shaftline measurements will also be summarized in the analysis.

Approach

Analysis of the data will involve animated graphical display of the sensor responses. Ice loads will be calculated using the calibration factors obtained. This will involve the following work:

- Hard copies of the time history waveforms will be produced
- The ice conditions and measurements will be summarized and documented
- The frequency and severity of ice loads on the nozzle will be calculated and will include an estimate of the following:
  - Longitudinal and Transverse Force
  - Effective Stiffness, Natural Frequency, and Damping Characteristics
- The frequency and severity of ice loads ice loads on the stem tube bearings will be calculated and will include:, Local Bearing Pressure, Total Vertical Load, Total Transverse Load
- Shaftline response values will be determined and will include the following:
  - Intermediate bearing vertical and transverse load
  - Shaft Torque, Thrust, and Bending
  - Shaft movement forward of the stem tube seal
  - Shaft RPM, Propeller Pitch, Engine Fuel Rack, Rudder Angle
- Maximum values of all ice loads will be calculated and related to open water loads
- Results will be compared to proposed design criteria and CASPPR regulations for ice class nozzles
- Comparison of loads measured with the data from the M.V. Kalvik (open propeller)
- Significant event data will be incorporated into the "Shaft Modeling Tool Kit" software package that was developed for TDC as part of a separate project.

Output

Estimated, stiffness, damping, natural frequency, and ice loads from measurements made on the nozzle and stem tube bearings, as well as the shaft line response (Torque, Thrust, etc.)

Task 10 Preparation and Presentation of Final Report

At the conclusion of the project a draft report will be prepared and submitted to all participants for review. Shortly after the submission a presentation of the results of the project will be conducted at a mutually convenient time and location. The report will include the details and results of each work task. It will also include recommendations and conclusions as a result of the analysis of the full scale data, and contain the following:

- Instrumentation and Data Collection Report
- Analysis of nozzle-ice interaction events
- Calibration results and methodology
- An assessment of the proposed regulations for the design of ice class nozzles
- Analysis of the bearing load response to ice/nozzle/propeller interaction
- Analysis of the shaftline response to ice/nozzle/propeller interaction
- Comparison of results with the open propeller data from the M.V. Kalvik tests

Upon receipt of the comments on the draft final report from participants, a final report will be produced and submitted to all participants.

3.3. RESEARCH PROJECT PERSONNEL

The proposed project organization is presented in Figure 3.5. Ian Glen of Fleet Technology will act as project manager and Bruce Cowper will act as principal engineer for the interests of Transport Canada. If a contract is established with NKF Engineering and the U.S. Coast Guard, Richard Voelker of NKF Engineering will act as project manager and James St. John will act as principal engineer for the interests of the United States Coast Guard. Bob Rushton and Ray Pierce will act as project managers for Gulf Canada Resources Limited, and will manage the northern logistics and ship deployment. Gulf, NKF, and Fleet will communicate on a continual basis to ensure that the project tasks can be completed as planned.

Fleet Technology in association with Gulf Canada will conduct the entire project if NKF Engineering and the U.S.Coast Guard are not able to contribute to the project, and sufficient funds are made available.

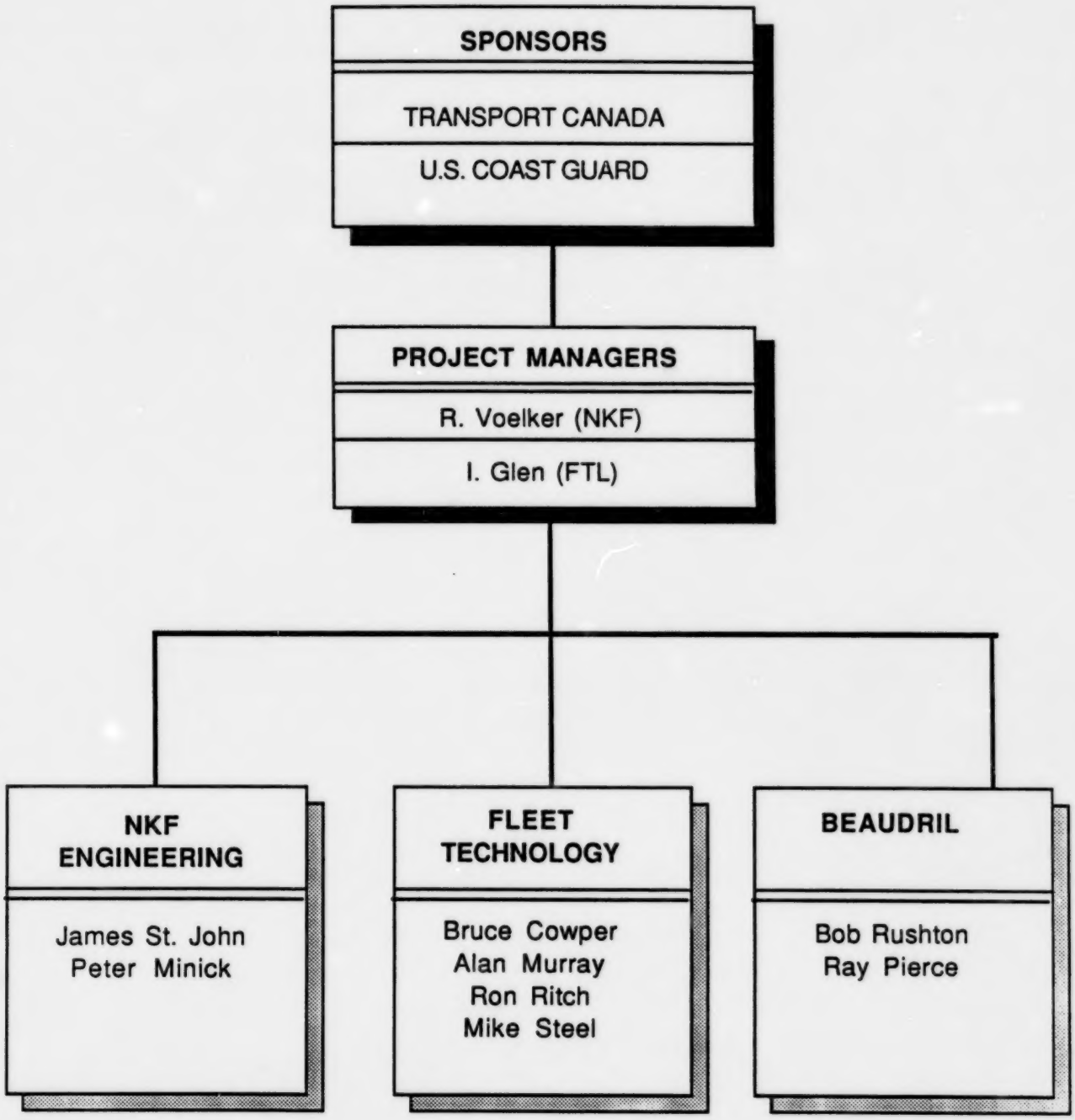


Figure 3.5 Research Project Organization

3.4 SCHEDULE

Key dates and action items are listed in Table 3.2, and the research plan project schedule is illustrated in Figure 3.6. Because of the fixed schedule of the drydocking work on the M.V. Ikaluk, April 1989, and the lead time for instrumentation design and procurement, the contract to proceed on this project should be awarded by February 1989. The trials period will be in June 1989 and the draft final report will be delivered in December 1989. The test dates are subject to some slight changes according to Gulf Canada's operations.

Table 2 Key Dates and Action Items

Date	Description
February	Contract awarded
March 1	Complete design of instrumentation system. Order strain gauges and related instrumentation. Develop Software.
March 25	Ice road from Tuktoyaktuk to Herschel Island complete
April 12	Depart for Herschel Island to install instrumentation
April 14	Begin instrumentation while M.V. Ikaluk in floating dry dock
April 28	Begin calibration
April 30	Ice road closed
May 2	M.V. Ikaluk removed from dry dock
June 1	Start field tests (5 days dedicated ship time)
June 5	Complete Dedicated Testing. Start 10 days data collection on an opportunity basis
July 3	Decommission instrumentation
July 10	Begin data analysis
September 15	Complete data analysis
October 15	Submit and present draft final report
December 15	Submit final report

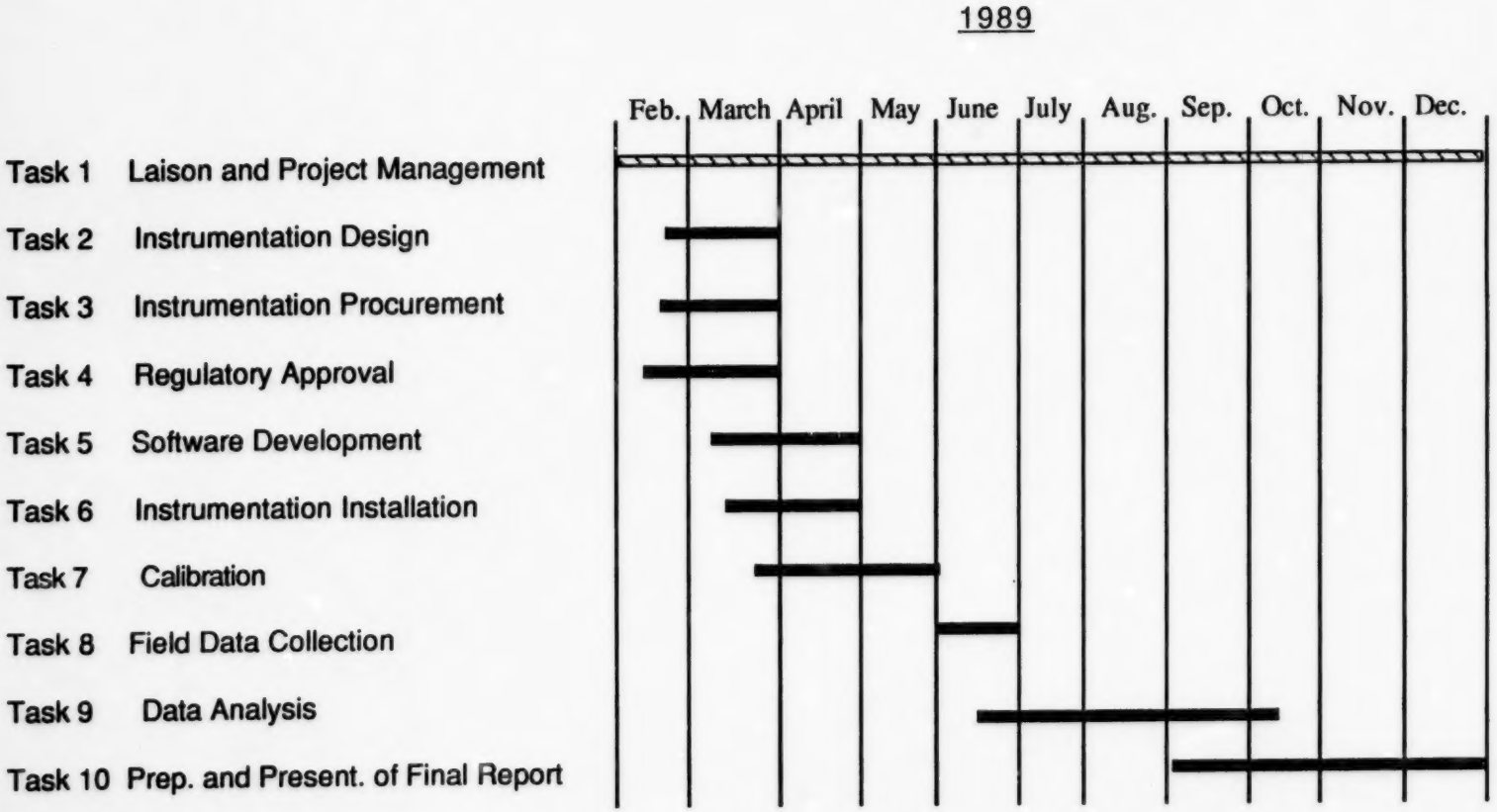


Figure 3.6 Research Plan Project Schedule

3.5. PROJECT COSTS

The cost breakdown for the research project is listed in Table 3. The total cost is to be shared equally between the U.S. Coast Guard and Transportation Development Centre.

Table 3 Project Costs

Costs	Task	TDC	USCG	Total
Task 1	Liaison and Program Management	$16,000	$13,000	$29,000
Task 2	Instrumentation Design	$11,500	$11,500	$23,000
Task 3	Instrumentation Procurement	$39,000	$39,000	$78,000
Task 4	Regulatory Approval	$6,000	0	$6,000
Task 5	Software Development	$8,500	$8,500	$17,000
Task 6	Instrumentation Installation	$62,000	$71,000	$133,000
Task 7	Calibration	$5,000	$5,000	$10,000
Task 8	Field Data Collection	$162,500	$162,500	$325,000
Task 9	Data Analysis	$39,000	$39,000	$78,000
Task 10	Preparation and Presentation of Final Report	$21,500	$21,500	$43,000
TOTAL		**$371,000**	**$371,000**	**$742,000**

Cost Break Down for Fleet Technology:

Category	Cost	*Percent of Work Completed with these Funds
Labour Plus Overhead	$165,000	55%
Subcontracts	$134,000	52%
Material/Equipment Purchases	$13,000	50%
Use of Fleet Technology Equip.	$11,000	50%
Equipment Rental	$5,000	50%
Travel/Accommodation	$13,000	65%
Communications and Other Expenses	$3,000	65%
Fee(Profit) (According to DSS Profit Policy Guidelines)	$27,000	
TOTAL	**$371,000**	

* The percent of funds are presented should Fleet Technology be required to perform all the work, the remaining funds required can be calculated.

Subcontracts:

1. Gulf Canada Limited, 50% of Ship Charter: 2.5 Days Charter @ $48,000 Day = $120,000.
2. Machinist and Welders, 50% of Machining and Welding costs $7,000
3. Independent consultant to provide services in evaluating proposed regulations on ice loads on nozzles based upon the results of tests, $7,000.

Costs for Additional Dedicated Ship Time

The M.V. Ikaluk will be made available to the participants for additional dedicated trials beyond the five days provided for in this research plan if this is requested and agreed upon prior to the end of the 1989 operating season. The vessel will be charged out at approximately $36,000 per day plus $12,000 per day for fuel based upon a 12 hour operation period.

3.6 CONFIDENTIALITY

Gulf Canada Resources Limited propose that the results of this work be held confidential to the participants in this work and themselves for a period of three years. This is not to in any way limit the ability of Gulf or any of the participants to make use of the data internally and for their own purposes but is intended to govern the disclosure of the results of the work or the data to third parties not participating in this project.

3.7 ADDITIONAL PARTICIPANTS

Gulf propose that the participation of additional parties not named in the present research plan be considered and approved only with the mutual consent of all participants.

4.0 CONCLUSIONS

The following are the conclusions derived as a result of this project:

1. It is feasible to instrument the M.V. Ikaluk's nozzle, bearings, and shaftline to measure their respective response to ice loads.
2. There has been no significant damage to any of the nozzles on icebreakers operating in the Beaufort Sea. Therefore, it may be that the current design practices are too conservative and costly.
3. Damage to stern tube bearings and the internals of the propeller hub have occurred on vessels fitted with nozzles.
4. Icebreakers with a draft of less that 7.0 m and fitted with nozzles experience severe blockage of the nozzle such that the performance of the vessel is compromised.
5. The research plan presented should start by March 1, 1989 to ensure the instrumentation be completed before the undocking of the M.V. Ikaluk.
6. It is recommended that the research plan as presented be implemented. It offers a unique opportunity to collect data to enhance the technological development of icebreaking in Canada, and provide the needed full scale data to develop regulations pertaining to ice class vessels.

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